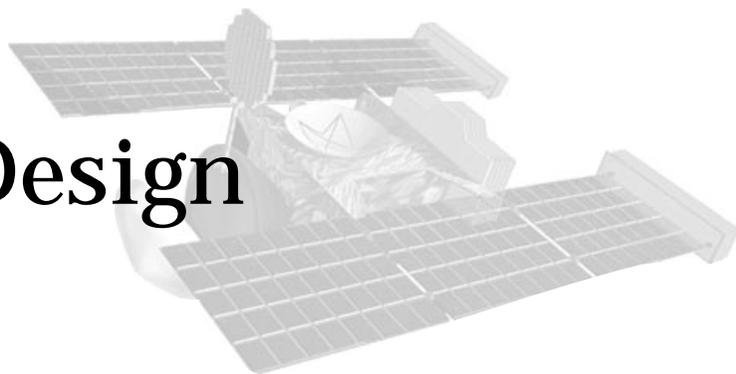


Spacecraft Design & Testing



Careful spacecraft design and testing ensure the success of a mission. Some factors that enter into the design include:

- ◆ Weight- The heavier the spacecraft, the more expensive it is to launch.
- ◆ Launch stresses - The instruments need to be sturdy enough to survive the force of rocket liftoff.
- ◆ Temperature extremes - In the hostile environment of space, the side of the spacecraft facing the Sun reaches temperatures of 120° C (248° F), while the other side plummets to -120° C (-184° F).
- ◆ Mission objectives - In the case of STARDUST, instruments will: test composition of interstellar particles as well as coma particles; collect samples of each; protect the spacecraft from high-speed comet debris; and safely return the sample return capsule through Earth's atmosphere for study.
- ◆ Spacecraft operation - All spacecraft require instruments and systems to monitor the health of the spacecraft, send and receive communication with mission control, supply power, and navigate the spacecraft.

This section contains activities that examine the STARDUST spacecraft and design an effective Sample Return Capsule.

- ◆ **Candy Model Spacecraft** - Uses a variety of candies and cookies to design a model of STARDUST and discusses the operation of each part of the spacecraft.
- ◆ **Egg Drop Sample Return Capsule** - Challenges students to develop a capsule with comet and interstellar particles (an egg) to re-enter Earth's atmosphere – that is, survive a two-story (30-foot, or 9-meter) fall – and return safely (without breaking) to Earth.

Candy Model Spacecraft



Overview

Students work in teams or individually to build the STARDUST spacecraft from candy, cookies, and popsicle sticks. Each student becomes a specialist, researching the function of part of the spacecraft.

Objectives

- ◆ To build an edible model of the STARDUST spacecraft.
- ◆ To identify the technology used on board the STARDUST spacecraft.

Preparation

This activity may be done individually or in teams of 3-4 students. Reproduce the STARDUST Spacecraft Fact Sheets for each team or individual. Fill a paper lunch bag with snack-size baggies of the materials listed below for each team. One can of icing can be separated into mini papercups and covered with plastic wrap. Many grocery stores sell cookies and candy in bulk, which is less expensive and which allows you to get as much or as a little of an item as you need.

Materials Needed

Try an assortment of the following candies and cookies:

- Graham crackers, sugar wafer cookies, rectangular crackers, or chewing gum in foil (Solar Arrays)
- Plain chocolate bars or mini chocolate bars, unwrapped gum (Dust Flux Monitors/Whipple Shields)
- Lollipops (Aerogel Dust collector)
- Mini peanut butter cups and large marshmallows (Sample Return Capsule)
- Small boxes of candy: Nerds, M & Ms, Good & Plenty (Main Body of Spacecraft)
- Small coated candies or cake decorations (Navigational Camera)
- Ready-made icing in tubes or a tub
- Toothpicks, popsicle sticks, pretzel sticks, wooden skewers
- Pretzel sticks, Twizzlers (Cometary and Interstellar Dust Analyzer)
- Toothpicks with small peanut butter cups or Rolos (Antennae)
- Peppermint patty (Launch Adapter)
- Construction paper to label parts
- Paper towels
- Brown lunch bags
- Small paper cups
- Plastic wrap
- Plastic snack bags
- Plastic gloves

Timeline

1-2 class periods

Key Question

What are the main parts of the STARDUST spacecraft?

What function does each part serve?



Management

This activity works well when done with individuals as well as in teams. Remind students that they will present their spacecraft to the class, so they are not to eat all of the candy. Icing holds the smaller parts together very well.

For stability, the solar arrays need to be connected to the body of the spacecraft. Toothpicks may not be appropriate for younger students to use. Try pretzel sticks, lollipop sticks, or popsicle sticks with icing.

You may want to take pictures of the spacecraft for each student to take home, or to put on a class or school webpage.



Procedures

1. Review the STARDUST mission to Comet Wild 2. (See the STARDUST Fact Sheet.)
2. Students will make a model of the STARDUST spacecraft.
3. Have students arrange desks into teams or work individually.
4. Have a student pass out a copy of the Spacecraft Fact Sheets to each group or individual.
5. Team members will do a jigsaw with the parts of the spacecraft, where each team member becomes the “expert” for one or more parts of the spacecraft. They are to read about the part on the fact sheet and then share their information with the group.
6. Pass out the bags of candy. Tell the teams that they will now build a model of the STARDUST spacecraft with the items in the bag.
7. Once the spacecraft is built, they will need to label the parts using toothpicks and construction paper labels.
8. Make a class presentation about how the spacecraft operates during the mission. Have the teams share their spacecraft models with each group explaining one part and its function to the class.
9. Direct students to clean up supplies.

Reflection Questions

1. What did you learn about the STARDUST spacecraft that you found interesting?
2. What are the major parts of the spacecraft?
3. What does each part do?
4. What was difficult about making your model?
5. What do you like best about your model?
6. Are there more instruments on STARDUST to do the cometary science or to operate the spacecraft? Why is that?





Spacecraft Rubric

A completed spacecraft should contain the following: 3 antennae, 2 solar arrays, 1 aerogel collector, 1 Whipple Shield, launch adapter, CIDA (dust analyzer), sample return capsule, and a 3-part camera.

Use the rubrics below to evaluate your students' model spacecraft.

- 4 = Complete, fully developed, everything accounted for. Very accurate, shows a high level of creativity.
- 3 = Mostly complete, most things accounted for, accurate, creative.
- 2 = Partly complete, parts are missing, some inaccuracy, shows very little creativity.
- 1 = Missing or omitted parts, mostly inaccurate, poorly put together.
- 0 = Did not create a model.

Presentation Rubric

Use the rubric below to evaluate the students' spacecraft presentations.

- 4 = All parts labeled, functions defined, student's explanation is clear and accurate.
 - 3 = Most parts labeled, some functions defined, explanation clear and accurate.
 - 2 = Some parts labeled, few or no functions defined, explanation confusing and inaccurate.
 - 1 = Few parts labeled, functions not defined, little or no explanation.
 - 0 = No presentation.
-



Egg Drop Sample Return Capsule



Notes

Overview

In 2006, the STARDUST mission will be the first mission to bring back captured particles of a comet's coma for scientists to study. The particles will be safely embedded in the aerogel dust collector and stowed in the Sample Return Capsule (SRC). The SRC is an aerodynamic canister with a heat shield, hinge, avionics equipment, double parachute system, and of course the sample container. It must withstand the heat of re-entering Earth's atmosphere, deploy a double parachute, and land intact in a dry lakebed in Utah, in order to bring these clues back to Earth.

Objectives

- ◆ Design and test a Sample Return Capsule to keep an egg from cracking when dropped from a second-story window.
- ◆ Calculate the components of free fall, including: time, speed, and distance.

Preparation

Be sure to get the approval of the principal to conduct this activity. Send a note home prior to the activity to collect a supply of materials needed.

Management

Have students work in teams of four. For younger students, the emphasis of the challenge can be steered away from calculating forces of gravity and placed on the strength of structure shapes. For example, circles and triangles are stronger structures than rectangles and squares.

Materials Needed

- | | |
|---------------------------------------|---|
| <input type="checkbox"/> Straws | <input type="checkbox"/> Thread |
| <input type="checkbox"/> Paper towels | <input type="checkbox"/> Paper |
| <input type="checkbox"/> Cottonballs | <input type="checkbox"/> Tape measure, yardstick, etc. |
| <input type="checkbox"/> Plastic bags | <input type="checkbox"/> Drop cloth |
| <input type="checkbox"/> Eggs | <input type="checkbox"/> Stop watch |
| <input type="checkbox"/> Scissors | <input type="checkbox"/> Styrofoam and cardboard containers |
| <input type="checkbox"/> Wire springs | |

Procedures

1. Set the scene properly, before you bring up the topic of the egg drop. The discussion should center around the problems of the Sample Return Capsule surviving re-entry into Earth's atmosphere and the impact of landing.
2. Which variables can be controlled? Which can be measured? Which can be calculated? One should discuss which factors have the greatest influence upon the forces of impact and which do not.

Does the mass of the package have any effect? What about the dimensions and shape? What about the falling distance? What about the falling time? What about



Timeline

3 to 5 classes

Key Question

What structures are strong enough to protect a raw egg from breaking when it is dropped from a two-story building?



the amount of weight crushing of the container? What was the average velocity? What was the terminal velocity? The total amount of “g” force absorbed by the package? Did the package or the payload absorb the force?

These are some of the factors which should be discussed before deriving a formula to determine the g forces of impact from those values which can be easily measured.

3. Introduce the exploration challenge: This is an exercise in using one’s ingenuity to package a delicate object (the egg represents the aerogel dust collector holding interstellar and comet dust particles) to withstand impact or a high “g” force by dropping it from a two-story window.

Their task is to package a raw egg in a container no larger than 6 x 6 x 6 inches (15 x 15 x 15 cm), (perhaps a hamburger box or some container which is easily obtained) so it can be recovered unharmed (the shell and the yolk should not be broken) when dropped from a 2-story window (height of at least 30 feet).

4. Break the class into teams of 3 or 4 students. Give students one to three class periods to explore the effects of changing container designs.
5. Drop the package from the given altitude.
6. Make appropriate measurements as indicated below.

Calculate the g forces of impact.

FORMULA TO DETERMINE g FORCES ON FALLING EGG

Input: DF = Distance of fall (in feet)

TF = Time for fall (in seconds)

Output: $g = D/32$ ft per second per second

7. Recover packages and bring them to a central site for opening.
8. Examine the contents of the package to determine the various levels of success:
 - ◆ Shell intact, yolk intact: complete success.
 - ◆ Shell intact, yolk broken: partial success
 - ◆ Shell broken, yolk intact: partial success
 - ◆ Shell broken, yolk broken: mission failure
9. Discuss the results as a class.

Reflection Questions

1. How many teams had complete success with their SRC? How many teams fall in each scenario listed in procedure 8? Convert these numbers to percentages.
2. What characteristics do stronger containers have?
3. What structures did not work well?
4. How would you redesign your container based on lessons learned from acquired data?
5. How does this egg drop experiment relate to the STARDUST mission?
6. Have humans ever brought back samples from a body in the Solar System?



Calculate:	AV = Average Velocity	AV = DF/TF
	TV = Terminal Velocity	TV = $2 \times AV$
	D = Deceleration	TC = $2 \times CD/TV$
	G = g forces	D = TV/TC

Egg Drop Sample Return Capsule Worksheet



Team _____ Date _____

_____ Class _____

Your Mission:

Package a raw egg in a container no larger than 6 x 6 x 6 inches, so it can be recovered unharmed (the shell and the yolk should not be broken) when dropped from a 2-story window (height of at least 30 feet).

1. How will you protect the egg? _____

2. Draw a sketch of the container, label all key elements.

3. Why did you choose this design? _____

4. What happened when you tested your team's design? Explain. _____

